Occupational Exposures and Salivary Gland Cancer Mortality Among African American and White Workers in the United States

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We conducted a large death certificate-based case-control study to assess occupational risks for salivary gland cancer. African American (168 cases, 672 controls) and white (2237 cases, 8748 controls) cases from 24 states (1984–1989) were matched to controls by age, sex, race, and region. Race- and sex-stratified multiple logistic regression models calculated adjusted odds ratios. The proportion of young cases (<50 years) was greatest among African Americans (20.8% vs. 8.8%). Higher socioeconomic status, ionizing radiation, formaldehyde, solvents, outdoor work, and animal contact were associated with elevated risk among white men. Physical activity reduced mortality risks among men, although significantly only among whites. Odds ratios for formaldehyde, solvents, benzene, and animal contact were 2.0 or greater among African American women, although not statistically significant. These findings suggest occupational and demographic factors needing further investigation. (J Occup Environ Med. *2004;46:287–297*)

Although cancers of the salivary gland are rare and the etiology unknown, previous studies have suggested a role of occupation. Elevated risks for salivary gland cancer have been reported among cosmetologists,[1] plumbers,[2] and workers in the agriculture,[3] auto,[4] fertilizer,[5] and rubber,[6–8] industries, although these findings are limited by the small number of cases studied. Salivary gland cancer is unlike more common malignancies of the oral cavity in that it has not been associated with smoking and/or alcohol use,[1,3,9–11] although a positive association with alcohol consumption in women[12] and cigarette smoking in men[6] has been reported. Ionizing radiation is the most consistently associated risk factor, including therapeutic irradiation,[12–15] medical and dental x-rays,[11,16] occupational radiation exposure,[6,17] and exposure to atomic bomb blasts in Japan.[18–20] A role of the Epstein-Barr virus (EBV) has been suggested by studies of viral DNA in tumor tissues and antibody profiles.[21,22]

The incidence of salivary gland cancer is approximately 1 per 100,000 in the United States and is slightly higher among men than women overall. However, incidence is higher among women in younger age groups (<40 years) and preponderance by sex is dependent on the histologic subtype.[23,24] African Americans experience higher salivary gland cancer mortality at young ages (<40 years) compared with whites.[25] Worldwide, the highest in-

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cidence occurs among Alaska Natives and Native peoples of Greenland.[26–28] Increases in incidence have been reported in at least 2 geographic areas of the United States (Connecticut and San Francisco–Oakland),[29,30] although this trend has not been found more broadly within the United States.[23]

The majority of cancers occur in the parotid gland (approximately 80%), with better prognosis than those occurring in the submandibular, sublingual, and minor salivary glands.[31] Histopathologic prevalence is dependent on the gland of involvement, with the major parotid tumors being carcinoma ex-pleomorphic adenoma, mucoepidermoid, adenocarcinoma, adenoid cystic, squamous cell, and acinic cell. Estimates on the prevalence of these histologic types vary, and histopathologic classifications for salivary gland malignancies continue to evolve.[24,32,33] The 10-year relative survival rate for salivary gland cancer is approximately 70% but varies considerably according to the tumor's anatomic location, histologic subtype, stage, grade, and extent of facial nerve invasion.[24,31,32,34]

The present study was designed to examine the relation between salivary gland cancer mortality and demographic and occupational exposures among African American and white men and women in the United States. The database included demographic, occupation, and industry data from 2505 salivary gland cancer deaths in 24 states. This is the largest study of salivary gland cancer that we are aware of to date.

Materials and Methods

Cases were identified through the National Cancer Institute, National Institute for Occupational Safety and Health, and National Center for Health Statistics death certificate database. In this database, 24 participating states provided occupation and industry titles on all death certificates starting in approximately 1984. Persons aged 20 and older dying of cancer of the salivary gland (International Classification of Diseases, version 9 [ICD-9] codes 142.0, 142.1, and 142.9) between 1984 and 1989 were included in the analysis. Controls dying of noninfectious causes were randomly selected and frequency-matched for age (within 5 years), race (white or African American), sex, and region* of the United States, with a case to control ratio of 1 to 4. Controls dying of infectious causes were excluded as a result of a suspected viral etiology of salivary gland cancer.

From the death certificate, occupation and industry were coded according to the 1980 U.S. Census Bureau 3-digit classification system, which includes 231 industries and 509 occupations.[35] Based on these codes, a job-exposure matrix (JEM) was developed using the method of Dosemeci et al., some of which has been used in previous analyses.[36–38] JEM scoring of unique occupation and industry code combinations was conducted by an industrial hygienist (MD) blinded to the case/control status of subjects, and based on professional assessment using the general industrial hygiene literature and the Integrated Management Information System of the Occupational Safety and Health Administration. Two types of JEMs were created. The first estimated simply the level of occupational exposure to animal contact, public contact, outdoor work, and physical activity (type 1). The second type of JEM included more in-depth assessment of probability, intensity, and confidence estimates of exposures to asbestos, benzene, formaldehyde, ionizing radiation, lead, and solvents (type 2). No other occupational data were available. Socioeconomic status (SES) was assigned to 1 of 5 categories based on occupation according to the method of Green et al.[39]

Chi-squared tests (2-sided) were used to determine statistically significant differences between cases and controls in geographic and demographic variables. Multiple logistic regression was used to adjust mortality odds ratio (OR) estimates for possible confounding factors. Crude and adjusted odds ratios were calculated for each 3-digit occupation and industry category, with adjustment for age (5-year age group) and marital status (single, married, widowed, divorced, unknown). Results are presented for those occupation and industry categories with at least 5 cases and a statistically significant odds ratio ($P < 0.05$), an odds ratio greater than or equal to 1.5, or an odds ratio less than or equal to 0.5. Job-exposure matrix odds ratios were adjusted for the effects of age, SES category, and marital status. Tests for the statistical significance of trend (2-sided) in the JEM variables were conducted using multiple logistic regression with 0, 1, 2, 3, and 4 for increasing levels of probability and intensity of job exposure. We examined possible interactions between SES and JEM variables by: 1) examining the odds ratios for each JEM within an SES strata and looking for nonoverlapping confidence intervals, and 2) examining the change in magnitude of the crosstabulated (SES by JEM) odds ratios in relation to one referent category to the determine whether a multiplicative relation (2-fold or greater) existed. We investigated risks in logistic regression models stratified by sex, race, and age (50 years and older and <50 years).

Results

Within the study population, 95.3% of white men and 87.3% of African American men had an occupation coded to the death certificate (Table 1). Among women, 45.0% and 30.9% of whites and African Americans, respectively, had an oc-

*Regions of the United States included the Northeast (Maine, New Hampshire, New Jersey, Rhode Island, Vermont), Southeast (Georgia, Kentucky, North Carolina, South Carolina, Tennessee, West Virginia), Central (Indiana, Kansas, Missouri, Nebraska, Ohio, Oklahoma, Wisconsin), and West (Colorado, Nevada, New Mexico, Utah, Washington, Idaho).

TABLE 1
Demographic Characteristics of Study Subjects and Corresponding Odds Ratios (OR) for Salivary Gland Cancer Mortality Risk, 24 U.S. States, 1984–1989

	White men		African American men		White women		African American women	
	No. (%)	OR* (95% confidence interval)	No. (%)	OR* (95% confidence interval)	No. (%)	OR* (95% confidence interval)	No. (%)	OR* (95% confidence interval)
Age at death								
20–39	160 (2.4)	†	25 (5.4)	†	115 (2.6)	†	45 (12.0)	†
40–49	430 (6.4)		80 (17.2)		280 (6.3)		25 (6.7)	
50–59	850 (12.6)		85 (18.3)		480 (10.8)		60 (16.0)	
60–69	1620 (24.1)		125 (26.9)		885 (19.9)		65 (17.3)	
70–79	1910 (28.4)		105 (22.6)		1110 (24.9)		85 (22.7)	
80+	1765 (26.2)		45 (9.7)		1580 (35.5)		95 (25.3)	
Total	6735 (100.0)		465 (100.0)		4450 (100.0)		375 (100.0)	
Occupational status								
Occupation indicated	6418 (95.3)	Reference	406 (87.3)	Reference	1914 (45.0)	Reference	116 (30.9)	Reference
Retired	54 (0.8)	0.4 (0.16–1.02)	8 (1.7)	0.6 (0.07–4.70)	18 (0.4)	1.5 (0.55–4.34)	1 (0.3)	‖
No occupation	256 (3.8)	**0.5 (0.31–0.69)**	51 (11.0)	1.1 (0.54–2.31)	86 (1.9)	**0.5 (0.23–0.92)**	21 (5.6)	0.6 (0.18–2.30)
Homemaker	7 (0.1)	‖	0	‖	2232 (50.2)	1.0 (0.84–1.13)	137 (36.5)	0.6 (0.33–1.06)
SES category‡								
1 low	1183 (18.4)	Reference	163 (40.2)	Reference	223 (10.6)	Reference	70 (32.4)	Reference
2 lower middle	1378 (21.5)	1.1 (0.87–1.29)	119 (29.3)	1.3 (0.71–2.34)	454 (21.5)	0.7 (0.45–1.07)	68 (31.5)	0.7 (0.31–1.57)
3 middle	2418 (37.7)	**1.3 (1.05–1.50)**	103 (25.4)	1.0 (0.52–1.90)	827 (39.1)	1.2 (0.86–1.81)	45 (20.8)	0.7 (0.27–1.78)
4 upper middle	1005 (15.7)	**1.6 (1.31–1.98)**	17 (4.2)	2.6 (0.87–7.83)	542 (25.6)	1.4 (0.92–2.00)	32 (14.8)	0.5 (0.15–1.40)
5 upper	434 (6.8)	**2.2 (1.72–2.84)§**	4 (1.0)	4.7 (0.63–36.08)	68 (3.2)	1.2 (0.61–2.33)	1 (0.5)	‖
Marital status								
Single	498 (7.4)	Reference	77 (16.6)	Reference	272 (6.1)	Reference	55 (14.7)	Reference
Married	4271 (63.4)	**1.8 (1.41–2.40)**	227 (48.8)	0.7 (0.34–1.35)	1468 (33.0)	**1.8 (1.26–2.56)**	100 (26.7)	1.2 (0.52–3.00)
Widowed	1210 (18.0)	1.4 (1.00–1.83)	73 (15.7)	0.9 (0.40–2.27)	2253 (50.6)	1.2 (0.85–1.72)	181 (48.3)	1.1 (0.43–2.75)
Divorced	745 (11.1)	1.1 (0.76–1.47)	84 (18.1)	1.2 (0.54–2.46)	453 (10.2)	1.2 (0.80–1.82)	38 (10.1)	0.3 (0.08–1.31)
Unknown	11 (0.2)	‖	4 (0.9)	‖	4 (0.1)	‖	1 (0.3)	‖
Total cases/controls	1347/5388		93/372		890/3360		75/300	

* Odds ratios (OR) adjusted by 5-year age group.
† Not applicable, matched on age group.
‡ Socioeconomic status (SES) based on occupation, excluding individuals recorded as retired, as a homemaker, or without an occupation.
§ Chi-squared test for trend $P < 0.001$.
‖ Odds ratios for categories with 4 or fewer exposed cases are not presented.

cupation coded on the death certificate. As shown by the odds ratios in Table 1, whites and African American women dying of salivary gland cancer were roughly half as likely to have no occupational coding compared with controls of the same racial group. Higher SES was associated with a higher mortality risk among white men (P trend <0.001), with a similar but not statistically significant trend among African American men (P trend $= 0.20$). A higher proportion of African American (20.8%) cases was under age 50 compared with whites (8.8%; $P < 0.001$, data not shown). Married white men and women were at a significantly higher risk of salivary gland cancer mortality, compared with unmarried persons, with a suggestive (not significant) increased risk among African American women but not African American men. The relation between marital status and salivary gland cancer mortality remained significant and similar in magnitude after adjustment for SES (data not shown).

Occupations associated with elevated salivary gland cancer mortality among white men included: managers (marketing, advertising and public relations), administrators (education), accountants, architects, chemists, physicians, and home furniture sales (Table 2). Among white men employed as janitors and cleaners, the risk was significantly lower (OR, 0.5; 95% confidence interval [CI] = 0.32–0.87). Among African American men, janitors and cleaners were at significantly higher risk (OR, 2.2; 95% CI = 1.01–4.61), whereas laborers were at a significantly lower risk (OR, 0.4; 95% CI, 0.14–0.98). Among white women, occupations with excess risk included administrators (education), elementary school teachers, real estate salespersons, typists, and supervisors (food preparation and service). African American women employed as cooks were at a significantly higher risk of salivary gland cancer (OR, 6.0; 95% CI = 1.47–24.13).

A significantly elevated mortality from salivary gland cancer among

TABLE 2
Salivary Gland Cancer Mortality Risk by Occupation, 24 U.S. States, 1984–1989*

Sex, race, occupation number, and title	No. of cases	OR† (95% confidence interval)
White men		
013 Managers: marketing, advertising and public relations	10	**2.6 (1.17–5.96)**
014 Administrators: education and related fields	9	**2.3 (1.00–5.38)**
019 Managers and administrators, not elsewhere classified	111	**1.3 (1.01–1.59)**
023 Accountants and auditors	23	**2.4 (1.43–4.06)**
036 Inspectors and compliance officers	7	2.4 (0.92–6.15)
043 Architects	5	**5.2 (1.38–19.60)**
053 Civil engineers	11	1.6 (0.79–2.27)
057 Mechanical engineers	9	2.1 (0.92–4.70)
073 Chemists	5	**4.1 (1.18–14.52)**
084 Physicians	15	**3.6 (1.75–7.24)**
154 Postsecondary teachers	5	2.9 (0.92–9.24)
176 Clergy	16	1.6 (0.89–2.88)
178 Lawyers	8	1.4 (0.63–3.22)
213 Electrical and electronic technicians	5	1.7 (0.60–5.06)
216 Engineering technicians	7	2.3 (0.88–5.90)
253 Insurance sales	15	1.5 (0.84–2.80)
266 Sales: furniture and home furnishings	5	**3.7 (1.06–12.83)**
417 Firefighting	6	2.1 (0.79–5.69)
418 Police and detectives	8	1.6 (0.68–3.62)
453 Janitors and cleaners	18	**0.5 (0.32–0.87)**
503 Supervisors, mechanics, and repairers	5	1.8 (0.61–5.30)
585 Plumbers	5	0.5 (0.19–1.23)
779 Machine operators, not specified	9	0.6 (0.20–1.08)
825 Railroad brake, signal, and switch operators	5	1.8 (0.62–5.32)
889 Laborers (excluding construction)	33	**0.6 (0.41–0.87)**
African American men		
453 Janitors and cleaners	12	**2.2 (1.01–4.61)**
889 Laborers, except construction	5	**0.4 (0.14–0.98)**
White women		
007 Financial managers	5	2.9 (0.93–8.90)
014 Administrators: education and related fields	6	**6.1 (1.70–21.85)**
156 Teachers, elementary school	41	**1.8 (1.23–2.63)**
243 Supervisors and proprietors, sales	20	1.5 (0.89–2.51)
254 Real estate sales	8	**2.9 (1.16–2.55)**
315 Typists	5	**4.8 (1.35–16.81)**
407 Private household cleaners and servants	18	1.6 (0.93–2.79)
433 Supervisors: food preparation and service	6	**6.7 (1.86–23.79)**
666 Dressmakers	6	2.6 (0.93–7.20)
796 Production inspectors, checkers, and examiners	8	1.6 (0.70–3.61)
889 Laborers (excluding construction)	6	0.5 (0.21–1.14)
African American women		
436 Cooks	5	**6.0 (1.47–24.13)**

* Odds ratios (ORs) presented include those occupations with 5 or more cases and statistically significant results ($P < 0.05$); or an odds ratio equal to 1.5 or greater; or an odds ratio of 0.5 or smaller (whether or not statistically significant).

† ORs adjusted for 5-year age group and marital status.

(Analyses excluding those classified as retired, homemaker, or without an occupation and results were not appreciably different.)

white men was associated with several industries: canned and preserved fruits and vegetables, telephone, electrical goods, machinery equipment and supplies, fuel and ice dealers, business services, physicians' offices, colleges and universities, engineering/architectural and surveying services, accounting services, educational and scientific research (Table 3). No industries were significantly associated with salivary gland cancer mortality among African American men, although some increases were observed for those employed in trucking services (OR, 2.8; 95% CI = 0.85–9.04), and elementary and secondary schools (OR, 2.8; 95% CI = 0.85–8.24). Among women, industries with significantly elevated risk included the following: U.S. postal service (white), private household cleaners (white), elementary and secondary schools (white), and agricultural production (African American).

Job-exposure matrix results are presented in Tables 4 and 5 for type 1 and type 2 JEMs, respectively. Among white men, occupations with animal contact and high outdoor exposure were significantly associated

TABLE 3
Salivary Gland Cancer Mortality Risk by Industry, 24 U.S. States, 1984–1989*

Sex, race, industry number, and title	No. of cases	OR† (95% confidence interval)
White men		
100 Meat products	5	1.8 (0.62–5.10)
102 Canned and preserved fruits and vegetables	5	**4.3 (1.24–15.09)**
182 Soaps and cosmetics	5	2.9 (0.90–9.13)
251 Cement, concrete, gypsum, and plaster products	6	2.3 (0.82–6.24)
350 Electrical machinery, equipment, and supplies	8	1.7 (0.73–3.88)
421 Air transportation	10	2.1 (0.96–4.49)
441 Telephone	17	**1.8 (1.01–3.24)**
512 Electrical goods	5	**3.7 (1.08–13.01)**
521 Hardware, plumbing, and heating supplies	6	2.1 (0.77–5.67)
530 Machinery, equipment, and supplies	12	**2.6 (1.22–5.32)**
672 Fuel and ice dealers	6	**3.8 (1.20–11.71)**
682 Miscellaneous retail stores	5	1.8 (0.64–5.36)
742 Business services	11	**2.4 (1.15–5.12)**
800 Theaters and motion pictures	6	2.6 (0.95–7.37)
812 Physicians' offices	12	**2.8 (1.32–6.00)**
850 Colleges and universities	20	**2.0 (1.18–3.52)**
882 Engineering, architectural, and surveying services	13	**2.2 (1.09–4.26)**
890 Accounting, auditing, and bookkeeping services	9	**3.2 (1.30–7.98)**
891 Noncommercial educational and scientific research	5	**4.4 (1.25–15.37)**
910 Justice, public order, and safety	25	1.5 (0.93–2.38)
930 Public administration	5	2.1 (0.72–6.30)
African American men		
410 Trucking service	5	2.8 (0.85–9.04)
842 Elementary and secondary schools	6	2.8 (0.85–8.24)
White women		
342 Electrical machinery (except household, radio and TV)	6	1.9 (0.73–5.18)
412 US Postal Service	7	**4.1 (1.44–11.93)**
601 Grocery stores	11	1.8 (0.88–3.69)
630 Apparel and accessory stores, except shoe	7	1.7 (0.69–4.17)
761 Private household cleaners and servants	22	**1.7 (1.04–2.85)**
842 Elementary and secondary schools	64	**1.4 (1.06–1.93)**
850 Colleges and universities	6	1.7 (0.64–4.43)
African American women		
010 Agricultural production, crops	5	**4.6 (1.18–17.68)**

* Odds ratios (ORs) presented include those occupations with 5 or more cases and statistically significant results ($P < 0.05$); or an odds ratio equal to 1.5 or greater; or an odds ratio of 0.5 or smaller (whether or not statistically significant).

† ORs adjusted for 5-year age group and marital status.

(Analyses excluding those classified as retired, homemaker, or without an occupation and results were not appreciably different.)

with excess salivary gland cancer mortality (Table 4). Similarly, excess risks (OR >4.0) were also seen in these categories among African American women, although confidence intervals were broad and based on a small number of cases. Among both African American and white men, occupations with moderate physical activity appeared to reduce salivary gland cancer mortality risk by 20% compared with sedentary occupations, although only statistically significant among white men (OR, 0.8; 95% CI = 0.19–3.69, and OR, 0.8; 95% CI = 0.61–0.99, respectively). There were no clear patterns of physical activity and salivary gland cancer mortality risk among women.

With respect to increasing intensity and probability of JEM exposures, we present results for those exposures scored with a mid to high level of confidence in the industrial hygiene assessment. Analyses including all confidence levels of the JEM were similar and odds ratios were slightly higher. Thus, we report the more conservative estimates here (Table 5). Among white men, the highest categories of ionizing radiation (OR, 1.7; 95% CI = 1.05–2.80, mid–high probability and mid–high intensity vs. low probability and low intensity, P trend = 0.08) and formaldehyde (OR, 1.6; 95% CI = 1.30–2.00, mid–high probability and mid–high intensity vs. low probability and low intensity, P trend <0.001) were significantly associated with elevated salivary gland cancer mortality risk. Although the test for trend was statistically significant for formaldehyde exposure among white men, there was not a dose-response pattern of monotonically increasing risk with increased exposure intensity

TABLE 4
Salivary Gland Cancer Mortality Risk by Job Exposure Matrix (type 1 JEM), 24 U.S. States, 1984–1989*

	White men		African American men		White women		African American women	
	OR (95% CI)	Exposed case/ control	OR (95% CI)	Exposed case/ control	OR (95% CI)	Exposed case/ control	OR (95% CI)	Exposed case/ control
Animals	**1.5 (1.17–2.12)**	128/477	0.4 (0.12–1.63)	3/29	0.3 (0.04–2.46)	1/14	4.3 (0.89–20.32)	5/5
Public	1.0 (0.79–1.16)	176/614	0.9 (0.30–2.45)	6/22	0.9 (0.69–1.13)	143/582	0.8 (0.31–2.05)	11/50
Outdoor Exposure								
None	Reference	709/2728	Reference	47/165	Reference	400/1546	Reference	43/150
Moderate	1.1 (0.91–1.22)	426/1647	0.7 (0.37–1.45)	19/85	1.1 (0.69–1.59)	32/112	1.0 (0.22–4.45)	3/10
High	**1.4 (1.10–1.78)**	183/730	0.8 (0.38–1.58)	15/75	0.4 (0.09–1.71)	2/22	4.3 (0.89–20.32)	5/5
Physical activity								
Sedentary	Reference	240 /691	Reference	6/9	Reference	139/489	Reference	3/20
Low	0.9 (0.76–1.19)	404/1491	0.4 (0.10–1.89)	17/91	1.2 (0.94–1.65)	158/545	Reference	11/38
Moderate	**0.8 (0.61–0.98)**	276/1219	0.8 (0.19–3.69)	26/75	0.9 (0.65–1.21)	101/499	1.4 (0.54–3.50)	19/64
High	1.0 (0.73–1.25)	393/1704	0.6 (0.12–2.63)	32/150	1.2 (0.69–2.12)	36/147	2.9 (0.59–14.56)	18/43

* Reference category is no occupational exposure (excludes retired, homemaker, and those without a recorded occupation). Odds ratio (OR) adjusted for age, marital and socioeconomic status, with 95% confidence interval (CI) in parentheses.

TABLE 5
Salivary Gland Cancer Mortality Risk by Job Exposure Matrix Exposure Probability and Intensity Level (type 2 JEM), White Men and Women, 24 U.S. States, 1984–1989*

Sex and job exposure (no. of exposed cases/ controls)	Low probability/ low intensity OR (95% CI)	Low probability/ mid–high intensity OR (95% CI)	Mid–high probability/ low intensity OR (95% CI)	Mid–high probability/ mid–high intensity OR (95% CI)	Trend *P* value
White men					
Ionizing radiation	0.8 (0.55–1.11) 46/223	0.7 (0.45–1.26) 18/102	1.4 (0.96–2.16) 34/90	**1.7 (1.05–2.80)** 32/47	0.08
Formaldehyde	0.9 (0.70–1.15) 88/391	0.7 (0.35–1.26) 11/70	2.4 (0.86–6.75) 6/10	**1.6 (1.30–2.00)** 31/779	<0.001
Benzene	1.2 (0.93–1.51) 104/358	1.1 (0.77–1.56) 44/185	1.1 (0.94–1.38) 209/785	0.9 (0.69–1.12) 99/487	0.96
Solvents	**1.4 (1.09–1.76)** 120/341	1.4 (0.92–2.06) 37/143	**1.2 (1.01–1.49)** 243/941	1.2 (0.97–1.45) 251/1056	0.06
White women					
Ionizing radiation	0.8 (0.17–3.88) 2/10	1.0 (0.58–1.76) 20/67	1.1 (0.48–2.42) 8/27	0.7 (0.42–1.29) 16/96	0.42
Formaldehyde	0.7 (0.33–1.28) 11/87	1.1 (0.54–2.07) 13/53	1.3 (0.63–2.60) 12/59	1.0 (0.73–1.49) 49/166	0.69
Benzene	1.6 (0.68–3.73) 8/19	1.3 (0.44–4.08) 4/18	0.6 (0.21–1.78) 4/28	0.8 (0.47–1.44) 16/81	0.45
Solvents	0.8 (0.50–1.22) 31/120	0/9	0.9 (0.57–1.41) 31/167	0.9 (0.62–1.40) 34/144	0.49

* Reference category is no occupational exposure (analysis excludes retired, homemakers, and those without a recorded occupation), and analysis limited to occupations with mid- and high-confidence level rankings for JEM. Odds ratio (OR) adjusted for age, marital status and socioeconomic status, with 95% confidence interval (CI) in parentheses.

and probability (odds ratios in Table 5 from left to right). Solvent exposure was associated with 20% to 40% excess mortality risk among white men, although the test for trend was not statistically significant ($P = 0.06$).

There were no significant risks among African American men or women for any of the job-exposure matrices (ionizing radiation, formaldehyde, benzene, solvents) analyzed by probability, intensity level, or probability and intensity together. Adjusted odds ratios among African American women were near 2.0 or greater for: moderate/high intensity of exposure to benzene (OR, 3.2; 95% CI = 0.70–14.31), formaldehyde (OR, 1.9; 95% CI = 0.75–5.06), and solvents

(OR, 2.4; 95% CI = 0.87–6.62) (adjusted for age, marital status, and socioeconomic status; data not shown). Interaction between SES and any of the JEM variables was not observed. Age-stratified results were not noteworthy.

Discussion

This is one of the first studies to explore occupational risks for salivary gland cancer among a large number of both African American and white individuals in the United States. The advantages of the study design include: the ability to analyze occupational risk factors for a rare cancer among a large number of cases and controls; the surveillance of cancer risk over a large geographic area; and uniform coding methods for occupation and industry in the participating study areas. In addition, the use of a JEM could add strength to the study design. Recall bias is one potential source of bias in case-control studies relying on self-reported exposure, which can be eliminated using a JEM. Although misclassification of job exposures cannot be eliminated using the JEM approach, it is expected that misclassification is nondifferential and generally resulting in reduced estimates of the true effect.[40]

This study was limited by the analysis of a mortality outcome (as opposed to newly diagnosed cases), underreporting of salivary gland cancer deaths on death certificates,[41] misclassification of occupation on death certificates, lack of information on occupational changes over the life course, or on other potential confounding variables such as nonoccupational radiation exposure. Misclassification of a metastatic skin cancer as salivary gland cancer could be a particularly important limitation. Both basal cell and squamous cell skin cancers could metastasize to the parotid gland and could present clinically as a parotid mass.[34,42] For squamous cell histologic types, exclusion of the parotid as a metastatic site is particularly difficult.[31,34] Historically, half of squamous cell parotid tumors have been found to be misclassified metastatic cancers of other head and neck sites.[43] In addition, we did not adjust for multiple comparisons; thus, statistically significant findings in some occupational categories could be the result of chance alone.

In the United States, individuals in the lowest socioeconomic strata generally bear the greatest cancer mortality burden.[44,45] In contrast to this overall pattern, we found that salivary gland cancer mortality increased with higher SES among white men, with a similar but not statistically significant association among African American men. It is not clear whether this could be a true association or an artifact of misclassification.[41,46] Because cancers of other head and neck sites are associated with low SES, a likelihood for greater (nondifferential) misclassification with decreasing SES exists.[47] Furthermore, case-control studies for salivary gland cancer have not been consistent with respect to SES-related variables. For example, in the United States, a case-control study by Spitz et al. found an excess of salivary gland cancer among those with a college education and white-collar work,[12] but Muscat et al. found no association with education level.[9] A population-based study by Zheng et al. in Shanghai, China, found a significantly higher risk of salivary gland cancer incidence among those with lower income.[11]

Among whites, salivary gland cancer mortality was higher among married compared with unmarried individuals. We hypothesized that marital status might be related to a greater number of contacts with infectious agents through family members and children. Although we did observe elevations of salivary gland cancer mortality in some occupations and industries with relatively higher public contact, this hypothesis was not corroborated by our JEM results for public contact, nor the results of another case-control study.[12] Similarly, Zheng et al. reported no association with greater family size. It is noteworthy, however, that the highest incidence of salivary gland cancers occur among Alaska Native and Greenland Native populations, which experience generally higher rates of household crowding at young ages and higher rates of infectious disease at young ages.[26,48,49]

Our findings were consistent with previous studies linking occupational exposure to ionizing radiation with salivary gland cancer, although previous occupational studies have been based on a small number of exposed cases.[6,17] Although the odds ratios among white men increased with the probability and intensity of occupational exposure, the trend was not statistically significant, and we did not find a similar relation among women or among African Americans. Possible reasons for this inconsistency include: the lower validity of occupation recorded on the death certificate as a measure of true occupational exposure among African Americans,[50] a lower power to detect an association among women and African Americans (exposed cases: 46 white women, 4 African American men, 4 African American women, compared with 130 white men), a potentially shorter duration of exposure among African American cases and controls who were significantly younger at the time of death compared with whites, and the possibility of greater nonoccupational radiation exposures in the African American control population compared with whites.[51,52] A previous analysis also found inconsistent results among white and African American women with respect to occupational ionizing radiation exposure and breast cancer risk when using a death certificate-derived JEM estimate of exposure.[53]

Among Japanese atomic bomb survivors, a well-recognized increase in salivary gland cancer occurrence with increasing radiation dose has been observed.[18–20] Because the oropharynx appears to be the primary

site of EBV infection, one possible mechanism through which radiation exposure could contribute to salivary gland carcinogenesis is through EBV infection reactivation.[54] This is suggested by the elevated antibody titers to EBV early antigen (EBV-ea IgG) among radiation-exposed survivors.[22] Similarly, EBV-positive Hodgkin's disease tumor cell lines exposed to ionizing radiation express proteins consistent with EBV reactivation.[55] Taken together, this suggests an interaction between EBV infection and radiation in salivary gland carcinogenesis.

There were 4 occupations with an elevated risk for salivary gland cancer in this study that have been previously reported, including agricultural production workers, fuel and ice dealers, machinery equipment and suppliers, and postal workers[1,12] Among agricultural production workers, exposure to nitrates and nitrosamines could be important.[5,8] We did not find statistically significant associations among rubber industry workers, plumbers, woodworkers, cosmetologists, or the auto industry, as found in other research.[1–8] Some of the inconsistencies among studies could be explained by differences in the industries located within the study area, differences in the reporting and coding of occupation, the analysis of newly diagnosed rather than deceased cases, and chance findings resulting from small numbers of cases analyzed.

Within this study, occupations and industries with consistent associations across race and/or sex groups included: education administrators (white men and women), colleges and universities (white men and women), elementary and secondary education (white women and African American men), and laborers (white men and African American men). Lack of consistency across race and sex groups could have been the result of comparatively less occupational exposure as a result of a higher proportion of salivary gland cancer mortality at young ages among African Americans and women, and other differences in exposure by race or sex that are not captured by the occupation recorded on the death certificate or the job exposure matrix. Figgs et al. found that white workers were assigned a higher proportion of high-exposure jobs in industries using formaldehyde compared with African Americans (42% vs. 23% above the median time-weighted average, respectively).[56] In contrast, a higher proportion of jobs with high occupational exposures to polycyclic aromatic hydrocarbons have been reported among nonwhite workers employed in the steel industry.[57] Agreement between occupational information derived from self-report compared with death certificate varies significantly by race.[58] Similarly, death certificates could more poorly estimate occupational exposures among women than men, and exposures among women within the same industry have been shown to differ significantly compared with men.[59] In addition, differences in occupational risk by racial group could also be linked to differences in the distribution of occupation within a particular industry. Because of the contrasting results by racial group for individuals employed as janitors in this study, we subsequently examined the industry of employment for janitors by racial group. Whereas nearly half (49%; 17 of 35) of African American janitors were employed in manufacturing-related industries, nearly all (97%; 157 of 162) white janitors were employed in industries related to professional and related services and public administration (codes 800–932).

Associations that are novel in this study include physical activity, outdoor work, formaldehyde, animal contact, and solvents. Moderate occupational physical activity was associated with a 20% lower risk of salivary gland cancer mortality in men, although only statistically significant among white men. In 1962, Taylor et al. reported lower overall cancer mortality among physically active workers.[60] To date, there is growing evidence for the role of physical activity reducing overall cancer risk and for risk of cancer at specific sites, including the breast and colon.[61,62] In general, studies have found a more pronounced effect among men for the reduction of overall cancer risk and for cancers of the colon.[63] Improved immune function and DNA repair capacity after moderate levels of physical activity have been cited as reasons for the protective association with overall cancer risk.[61,63]

With regard to outdoor work, salivary gland cancer incidence has been associated with ultraviolet radiation treatment to the head and neck,[6] a prior diagnosis of nonmelanoma skin cancer,[3,6,64–66] and a higher ultraviolet index within the Surveillance, Epidemiology and End Results (SEER) areas.[67] In contrast, an excess of salivary gland cancer has not been associated with cutaneous melanoma,[23,68,69] and salivary gland cancer mortality in the United States does not demonstrate a north–south gradient.[23,70] Future studies that incorporate pathologic review to avoid tumor misclassification are needed to clarify this association. Our findings in relation to a higher mortality risk among white men with occupational animal contact could be related to outdoor work because these two occupational exposures are correlated.

The possible role of formaldehyde was suggested by excess risks associated with formaldehyde exposure and certain occupations. Elevated risks were statistically significant among white men employed as physicians or furniture salesmen. The odds ratio for moderate to high formaldehyde exposure among African American women was approximately 2-fold, and there was a 2.6-fold elevated risk among white women employed as dressmakers, but these associations were not statistically significant. Other occupational groups exposed to formalde-

hyde (ie, textiles) were not at a significantly high risk in this study. Earlier epidemiologic studies have found textile work associated with buccal cancer mortality (inclusive of the salivary gland)[71] and salivary gland cancer,[12] although based on a small number of cases. A recent update to a textile workers cohort[71] did not find a sustained excess of buccal cancer mortality in recent periods (1983–1998), noting a greater likelihood of higher formaldehyde exposure in earlier time periods.[72] In a cohort of formaldehyde-exposed workers, Hauptmann et al. report elevated risks of salivary gland cancer mortality, which increased with cumulative exposure (ppm-years), although risks were not statistically significant and based on few (4) cases (M. Hauptmann, National Cancer Institute, unpublished manuscript). It is noteworthy that exposure to formaldehyde has been associated with elevated rates of micronuclei in exfoliated buccal cells of embalmers and higher frequencies of DNA protein crosslinks, mutant p53 tumor-suppressor protein expression, and sister chromatid exchanges in peripheral blood lymphocytes of formaldehyde-exposed hospital and laboratory workers.[73–78]

Occupational solvent exposure was associated with increased salivary gland cancer mortality among white men. Among African American women, risk estimates in excess of 2-fold were suggestive of an association with solvents and benzene. Solvents, including benzene, have been associated with cancers of several other sites, although not previously with salivary gland cancer.[79]

In summary, several occupational exposures were found to be associated with salivary gland cancer mortality among white men. These included ionizing radiation, physical activity, animal contact, outdoor work, formaldehyde, and solvents. This study is consistent with other studies linking occupational ionizing radiation exposure and certain occupation groups, including agricultural production work, fuel and ice dealers, machinery equipment suppliers, and postal work. Although several job-specific risks were found among women and African American men, the findings lacked overall consistency between race and sex groups. Such inconsistencies could be related to small numbers in certain exposure groups leading to a greater likelihood findings could be the result of chance alone, exposure misclassification, or a difference in the distribution of cofactors in the reference group.

This study provides supporting evidence for an association between salivary gland cancer mortality and occupational ionizing radiation exposure. The anomaly of higher mortality at younger ages among African Americans needs further research as do associations with physical activity, outdoor work, animal exposures, formaldehyde, and solvents.

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